RESEARCH ARTICLE OPEN ACCESS

Zigbee Network for Biomedical Signal Monitoring: Preliminary Results

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ABSTRACT
Wireless medical devices have been widely used inside hospitals, medical centers, ambulances and patients home. The wireless connectivity enable remote monitoring of patients' vital signs and improved care providers' ability to deliver timely treatment, leading to a better health care system. ZigBee is one of the technologies which have been widely used for wireless monitoring bioelectrical signals from patient freely moving. The objective of this work is to develop a wireless monitoring system for acquiring, monitoring and processing blood oxygenation, heart rate and body temperature. It is also presented a graphical interface for controlling and managing the ZigBee network devices. The ZigBee network was implemented by using the MC13213-EVK kit from Freescale Semiconductor and data were measured by the MED-SPO2 development kit. Additionally, the body temperature circuit was developed by using a negative temperature coefficient resistor. Data were recorded from 3 healthy volunteers of 25, 28 and 65 years old and recorded to a host computer. Comparisons were made by using commercial standard devices. The maximum error was found to be approximately 3.2% for the heart rate whereas a maximum of 1% for the others measured data. The network communication link between the sensors and the host computer was approximately 13 meters inside a room with walls but without using router devices. It can be concluded that the use of a wireless ZigBee system for monitoring and transmitting bioelectrical signals is feasible and it can be adjusted according to the patient needs. This might give to patient greater mobility for their daily activities during the day and it may also assist hospitals and medical centers with a great tool for monitoring and post-processing patients' vital signs.
Keywords - Biomedical Sensors, Signal Acquisition, Wireless Network, ZigBee.

I. INTRODUCTION

The concepts of the industrial automation have been widely incorporated in the medical area, as well as in hospital automation [1]. Medical industries have been developed many new devices in order to assist nurses and clinicians for monitoring vital signal in patients. One of the great challenges of patient monitoring is the mobility issue, since in most cases it is needed to stay connected to machines within a single room [2]. Most new technologies have become an essential stepping stone to providing the next generation devices for heath-point of care [3]. The new generations of medical devices use a certain level of wireless technology. The use of wireless technologies, which is called Telemedicine, might able to leverage the use of additional sensors, which provide deeper insight information about patient conditions [4]. Telemedicine involves the use of computer based systems for transmitting biomedical data and also remote control of medical devices [5]. It also may include monitoring, managing and processing data from many patients in a real-time scale [6].

Wireless medical devices have been widely used inside hospitals, medical centers, ambulances and patients home. Devices may include pacemakers, cardiac defibrillators, insulin pumps, and neuro-stimulators all feature wireless communication. The wireless connectivity enable remote monitoring of patients' vital signs and improved care providers' ability to deliver timely treatment, leading to a better health care system.

Most wireless devices use Bluetooth, Wireless USB, Wi-Fi, WiMax and ZigBee. The last has been used in medical applications over the last 8 years, which aims to collect many patient's physiological information from over hundreds ZigBee devices. This ensures accurate measurements and capability of storing hundreds of patient data when they are moving between hospital and home [7]. ZigBee is considered to be a short range, low power, low rate wireless networking over the IEEE 802.15.4 standard but complements the high data rate technologies such as WLAN and open the door applications [7]. This standard operates at the band of 2.4 GHz with a maximum rate of 250 kbps.

The objective of this work is to develop a wireless monitoring system for acquiring, monitoring and processing blood oxygenation, heart rate and body temperature. It is also presented a graphical interface for controlling and managing the ZigBee network devices.

II. Materials and Methods

2.1. System Architecture

The proposed system is shown in Fig, 1. It consists of a ZigBee network with coordinator device, which communicates via USB with a computer. This runs the software user interface and controls the sensor devices, which monitor the bioelectrical signals. The user interface was developed in LabView [8], allowing visualization of the data that are acquired by the ZigBee sensors network.

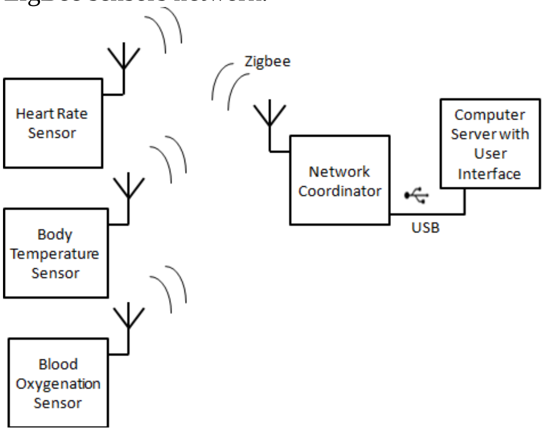

Figure 1: Diagram of the proposed wireless system.

The network coordinator device is responsible for forming the network and detects other sensors devices present on it. The coordinator keeps sending messages by requesting the data acquired by the sensor devices and then sends them back to the computer for the user visualization. The user can view the data graphics and then store them for post-processing and further analysis by the user.

2.1. Devices descriptions

The ZigBee network was implemented by using the MC13213-EVK kit from Freescale Semiconductor [9]. It contains the ZigBee radiofrequency transceiver with the HCS08 processor, digital and analog inputs, USB port and an embedded type F antenna. It is power supplied by batteries.

The communication between the network coordinator and the computer interface was performed by using the ZigBee test-client ZTC structure [10]. It also allows the communication between the layers of the ZigBee Protocol Stack. The network was implemented with the combined interface functionalities, as described by Freescale [11]. The biomedical sensors were configured as end-devices and 3 clusters were created, such as pulse oxymeter, heart rate and body temperature. The network coordinator works as a data accumulator and hence it is the only data path to the computer.

In order to measure the blood oxygen saturation index it was used the development kit called MED-SPO2 from Freescale Semiconductor, as shown in Fig. 2. It contains an oximeter sensor (model Nelcor DS100-A from Corvidien manufacturer) and a signal acquisition system. The communication between the MED-SPO2 kit and the MC13213-EVK kit was made by serial communication.

The heart rate was measured by an optical sensor, which contains a LED (light emitter diode) for emitting light through the fingertip or ear lobe and a photodiode for detecting the difference in brightness. The analog output of this sensor is measured and processed by the MC13213 development kit from Freescale Semiconductor.

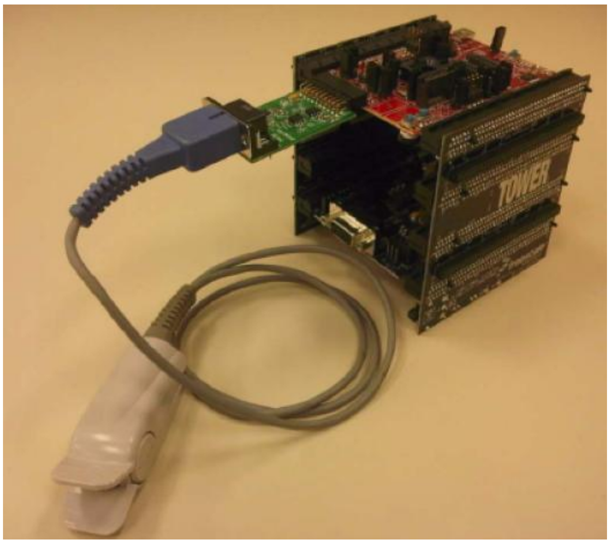

Figure 2: Photo of the MED-SPO2 development kit from Freescale Semiconductor.

In order to measure the body temperature, it was used a resistor with a negative temperature coefficient (NTC), as shown in Fig. 3. This is a voltage divider with an anti-aliasing filter, where VCC is the power supply, ADC is the analog to digital converter of the kit, R1=4,7 kΩ and C1=100 pF. The sensor was specified for a temperature range from 30 to 45 ºC. The sensor resolution is 0.1 ºC and the output voltage varies in a range of approximately 1.1 to 1.5 Volts.

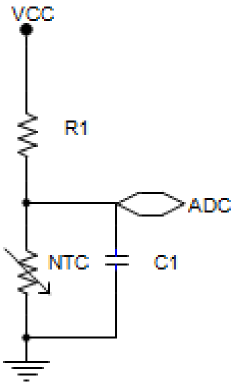

Figure 3: Diagram schematic of the body temperature sensor-circuit.

Fig. 4 shows the LabView graphical user interface developed for controlling, managing, storing and post-processing the measured signals. It allows the user to start and stop the network, to verify the connected devices, to start and stop the signal acquisition, to show the graphics and to store data in a text file format.

In order to investigate the performance of proposed system, three volunteers were selected for the measurements of the blood oxygenation, heart rate and body temperature. The blood oxygenation and heart rate were measured by the sensor positioned at the indicator finger whereas body temperature at the armpit. The volunteers are males and female aged 25, 28 and 65 years old, respectively. All the volunteers were monitored with one type of sensor. The results are compared to the commercial sensor systems.

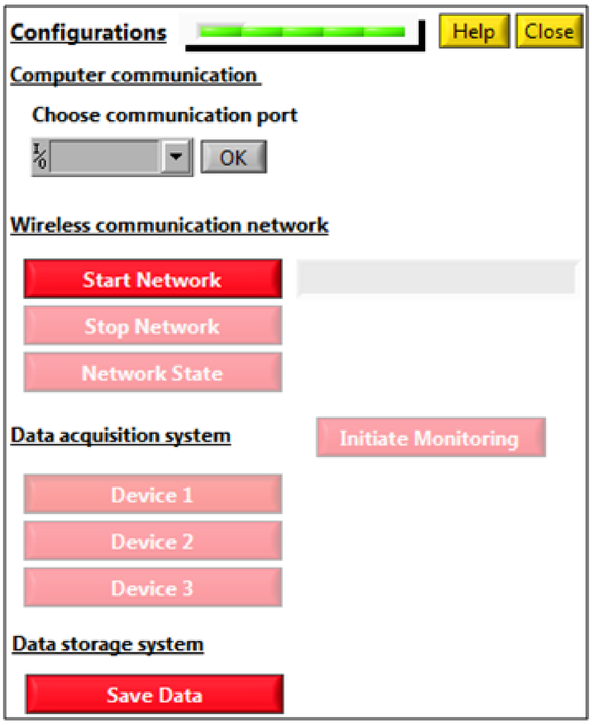

Figure 4: User graphical interface front panel.

III. RESULTS

The measured data from one volunteer are shown in Fig. 5, where the dashed line is the blood oxygenation index, the point-dashed line is the heart rate and the solid line is the body temperature. Data were recorded for approximately 77 seconds. It can be seen that the blood oxygenation (SpO2) is 97% and it is constant over time. The heart rate signal varied from 90 to 100 bpm (beats per minutes), which is expected for an adult man. It also shows that the measured body temperature was approximately 35.6 ºC, which took about 30 seconds to stabilize on that value.

In order to investigate the maximum distance for a good quality communication between the sensors and the host computer, it was set a test with the sensors. It was found that the sensors can be at a maximum distance of approximately 13 meters inside a room with walls but without using router devices.

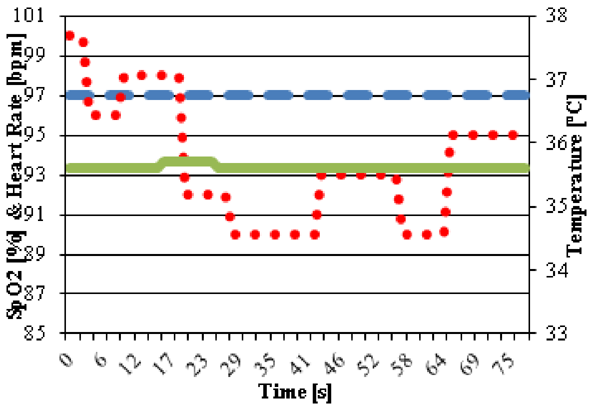

Figure 5: Time response of the measured bioelectrical signals by the proposed system.

Error! Reference source not found. shows the mean values when comparing the measured data taken by the proposed system to the ones taken by a commercial system. The commercial pulse and heart rate system used was the CMS50F. The blue bars represent the blood oxygenation, the red ones represent the heart rate and the body temperature data are shown by the green bars. The values shown in Fig. 6 are out of scale. The maximum error of approximately 3 bpm was found to be with the heart rate data. The maximum errors for the blood oxygenation (SpO2) was approximately 0.5% whereas 0.4 ºC for the body temperature.

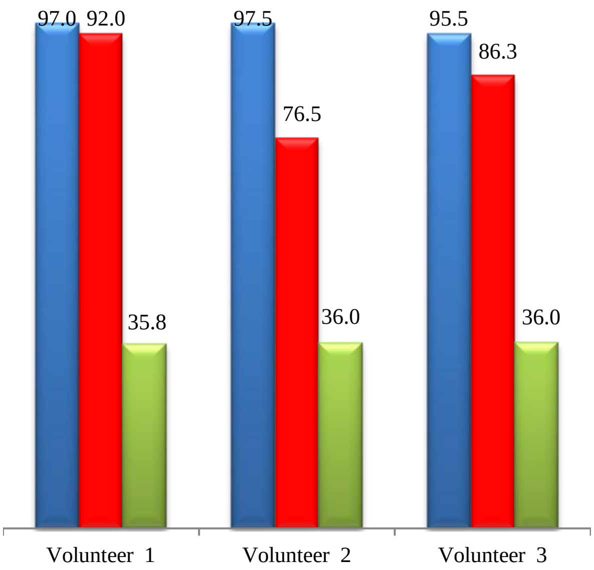

Figure 6: Measured bioelectrical signals from 3 volunteers.

IV. DISCUSSIONS AND CONCLUSION

The purpose of this work was the development of a system using the ZigBee wireless protocol to acquire bioelectrical signals, such as: blood oxygenation, heart rate and body temperature. Each signal was captured by a ZigBee device and then wireless connected to the ZigBee network coordinator.

The proposed system was customized and integrated to different commercial devices. The devices support either analog or digital outputs to be measured and then transferred by serial protocol to a host computer. The proposed system can be easily integrated with other networks or ubiquous systems allowing data storage and post-processing analysis.

Although ZigBee protocol allows large numbers of devices connected at the same time in the network by a coordinator, there are some limitations regarding sending and receiving messages. These limitations are due to lack of memory to store all the network address nodes for sending and receiving messages and to the narrow ZigBee network bandwidth.

The work described in this paper showed that the wireless ZigBee can be successfully used in the transmission of bioelectrical signals. The maximum error was found when measuring the heart rate, which might be explained by the fact that external light affects significantly the photodiode reception and then it affects the measured data. The graphical interface developed in LabView showed to be a flexible platform for monitoring the bioelectrical signals. It was also be able to identify all the parameters of the devices connected to the network, such as: network address and number of the device.

It can be concluded that the use of wireless ZigBee system for monitoring and transmitting bioelectrical signals is feasible and can be adjusted according to the patient needs. This might give to patient greater mobility for their daily activities during the day. It can also allow hospitals and medical centers with a great tool for monitoring and post-processing patients' vital signs.

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